REPORT ON TOPOGRAPHIC MAPPING PROJECT ON CHAPARE AREA, REPUBLIC OF BOLIVIA

(THIRD STAGE)

PART I. FIELD WORK

PART II. AERIAL TRIANGULATION

MARCH, 1977

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Republic of Bolivia, the Government of Japan has decided to cooperate in the topographic mapping project (Scale: 1/50,000, coverage: 20,000 Km^2) which is a prerequisite for planning of various development projects in Chapare area of the Cochabamba Province. Japan International Cooperation Agency (JICA) began to carry out the 1st phase work of the mapping project in the Fiscal year 1974 under a 4-year implementation program.

In the Fiscal year 1976 (the 3rd phase), JICA despatched a survey team headed by Mr. Seizo Kakishita and organized by the International Engineering Consultants Association (IECA) to Bolivia and conducted under supervision of the JICA's Supervisory Committee member, the ground control survey, (levelling, geodectic positioning by Doppler survey system) and field identification work for the period from mid-July to the end of October 1976. JICA also undertook the aerial triangulation work in Japan.

The 3rd phase work has successfully been completed although in the beginning many difficulties had been expected such as extreme different natural conditions which we never experienced before in carrying out mapping projects under Japan's technical cooperation programs. The successful completion of the 3rd phase work is solely attributable to the close cooperation and assistance extended by the officials concerned of both countries as well as the strenuous efforts of the survey team members.

Upon completion of the 3rd phase work, I wish to take this opportunity to express my heartfelt gratitude to the ministries concerned to the Bolivian Government, particularly Instituto Geografico Militar (IGM) and Corporacion de Desarrelle de Cochabamba (CORDECO), and other organizations concerned for their valuable cooperation and assistance.

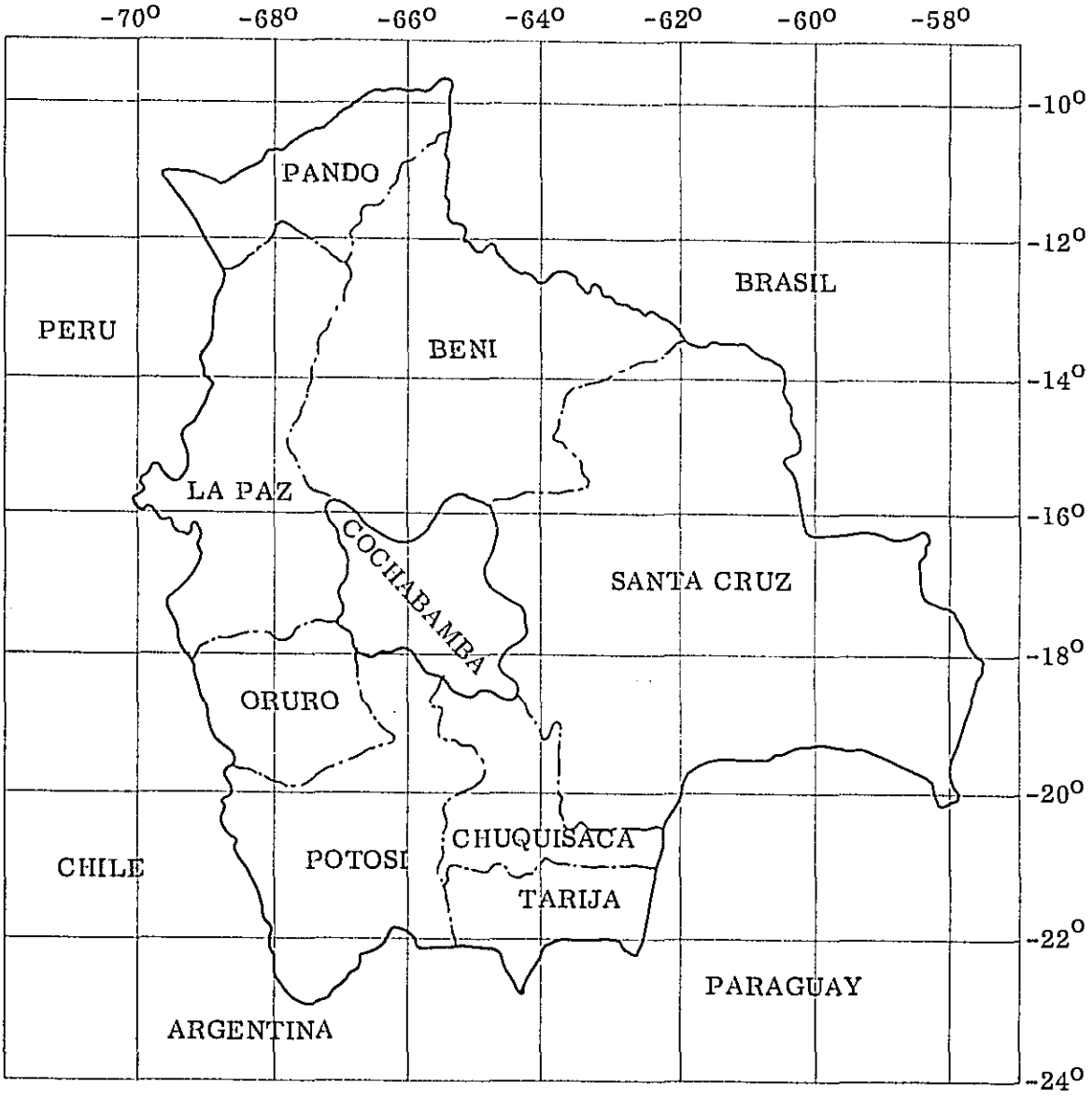
March 1977

Shinsaku Hogen

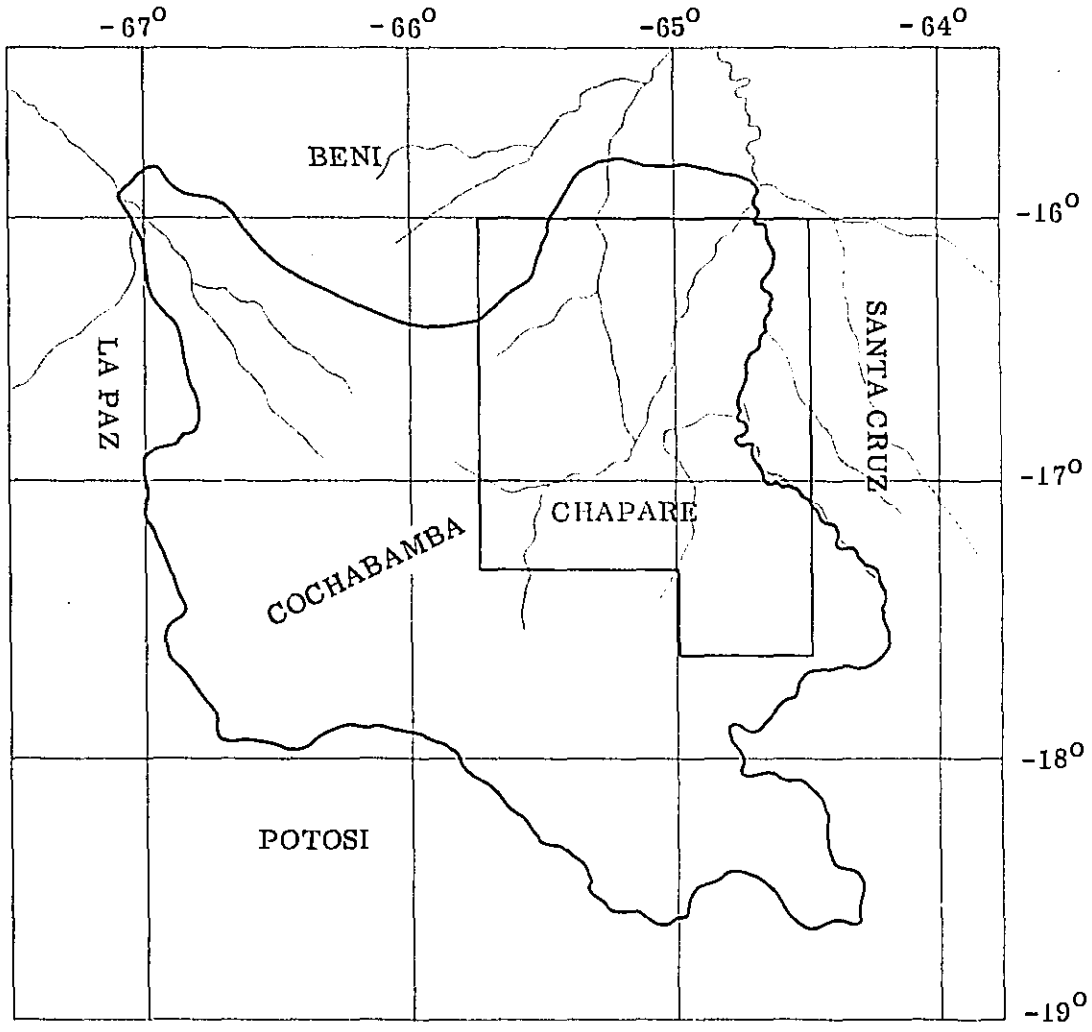
President

Japan International Cooperation Agency

Location Map of Cochabamba



Location Map of Project Area



Mr. Shinsaku Hogen
President
Japan International Cooperation Agency

March, 1977

I hereby submit this report on the works in the Third Stage of the topographic mapping project for the Chapare Area, the Republic of Bolivia, which were executed from July, 1976 in compliance with your request.

This report compiles the survey works conducted in the Third Stage (Field Work and Aerial Triangulation) following the First & Second Stages (Aerial Photography & Field Work) made in the fiscal year of 1975.

We are confident that the Japanese survey skills which were demonstrated through the operations and the result of the work in the Third Stage will also contribute very much toward progress and betterment of the Bolivian survey skills and the future development planning for the Chapare Area.

I would like to express again our heartful thanks to the Republic of Bolivia, the officials of the governmental agencies concerned and the officials of the Embassy of Japan in Bolivia for their continuous cooperation. And I also sincerely wish that the survey in the Fourth Stage and subsequent stages will be promptly conducted.

Very Truly Yours,

Seizo Kakishita
International Engineering Consultants Association
For Mapping Project of the Chapare Area, Bolivia

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PART I. FIELD WORK

(LEVELLING)

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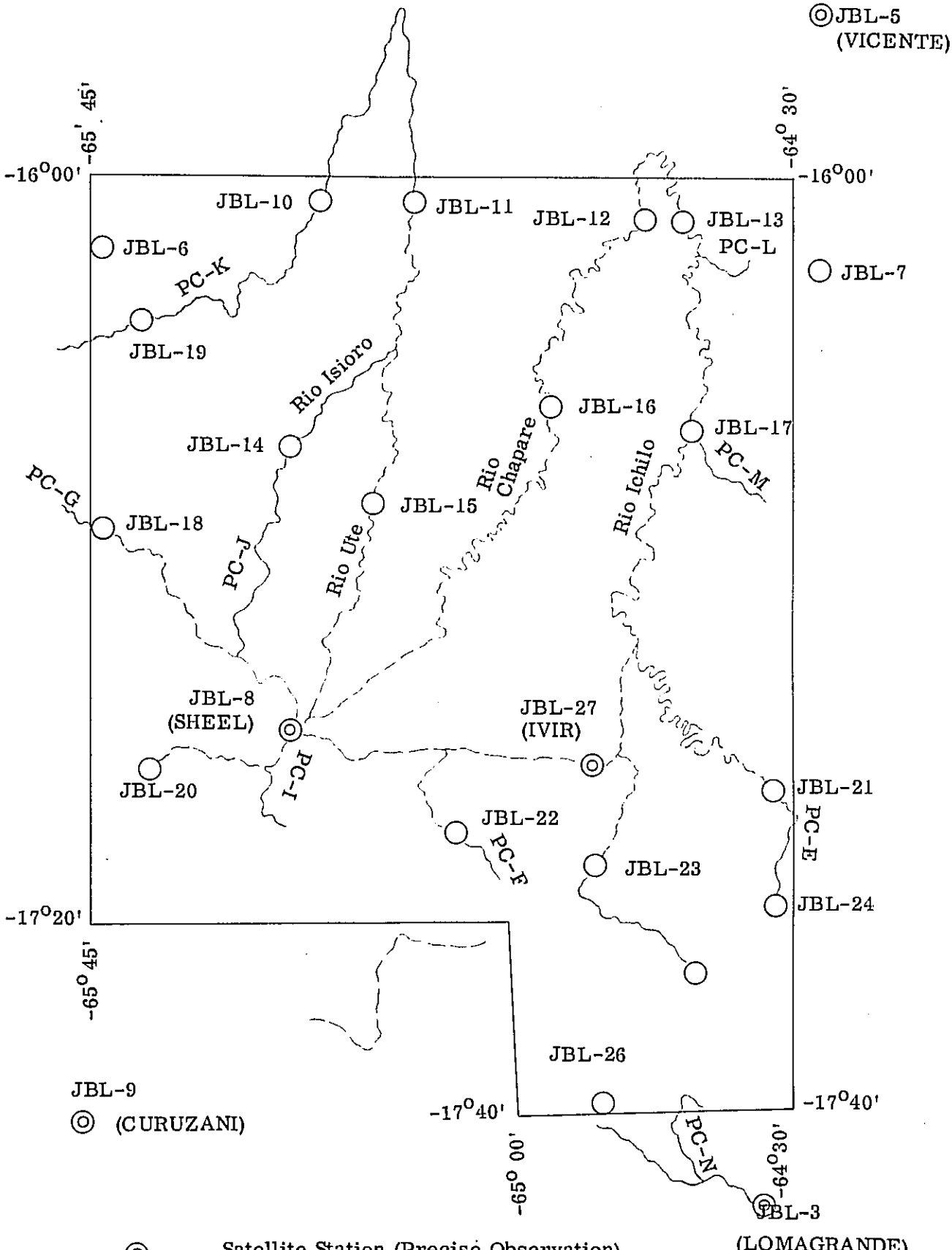
(FIELD IDENTIFICATION)


JBL-5
(VICENTE)
-65° 45'
-64° 30'
-16°00'
JBL-10
JBL-11
JBL-12
JBL-13
PC-L
JBL-6
JBL-7
PC-K
JBL-19
Rio Isioro
JBL-16
JBL-17
JBL-14
Rio Chapare
PC-M
Rio Ichilo
PC-G
JBL-18
JBL-15
PC-J
Rio Ute
JBL-8
(SHEEL)
JBL-27
(IVIR)
JBL-20
PC-I
JBL-21
JBL-22
PC-F
JBL-23
JBL-24
-17°20'
-65° 45'
JBL-26
JBL-9
(CURUZANI)
-17°40'
-65° 00'
PC-N
-64° 30'
JBL-3
(LOMAGRANDE)
Satellite Station (Precise Observation)
Satellite Station (Observation for 4 days)
Levelling Route (1st, 2nd Stage)
Levelling Route (3rd Stage)

A. OUTLINE OF THE FIELD WORK

1) Purpose

For the successive works of aerial triangulation and photogrammetric mapping at a scale of 1/50,000, the field works comprised of Levelling, Satellite Observation and Field Identification were conducted on the site in the Third Stage for the Chapare Area consisting of approximately 21,640 sq.km.

2) Survey Area

The survey area covered approximately 21,640 sq.km of the Chapare Area, the Republic of Bolivia.

3) Survey Period

The Japanese survey team left Japan on July 13, 1976 and returned on October 28, 1976 after completion of the scheduled works.

4) Members of the Japanese Survey Team

Leader : Mr. Seizo KAKISHITA, from July 13 to August 2, 1976 and from September 21 to October 11, 1976.

Sub-leader : Mr. Isao IKESHIMA, from July 13 to October 28, 1976

Liaison Officer: Mr. Yasuo IMANISHI, same period as above

Levelling : Mr. Sakuzo MIYAHARA, same period as above
Mr. Muneo WADA, from July 20 to October 21, 1976
Mr. Masao MIZOGUCHI, same period as above
Mr. Yasuro SATO, same period as above
Mr. Zenzo HAYASHI, same period as above
Mr. Tamotsu KUMAGAI, same period as above
Mr. Nobuo WATANABE, same period as above
Mr. Yoshinobu OHBA, same period as above
Mr. Takanobu NAKAZAWA, same period as above

(Bolivian) : Mr. Juan Heredia F, from July 25 to October 20, 1976
Mr. Enrrique Alipaz M., from July 25 to October 15, 1976
Mr. Eloy Mendoza M., same period as above

Mr. Rene Luma Ch., same period as above
Mr. Jose Lizarraga D., same period as above
Mr. Dodolfo Camacho O., same period as above
Mr. Jose Pinaya T., same period as above

Satellite : Mr. Yutaka NAKADA, from July 13 to October 28, 1976
Mr. Junichi KOSEKI, same period as above
Mr. Koji OSAKABE, from July 20 to October 21, 1976
Mr. Satoshi TAMURA, same period as above
Mr. Akira NISHIMURA, same period as above
Mr. Shozo TOYODA, same period as above
Mr. Fumio YOKOTA, same period as above
Mr. Masamichi SASAKI, same period as above

(Bolivian) : Mr. Eduardo Miranda J., from July 25 to October 15, 1976
Mr. Bravlia Paton M., same period as above
Mr. Alfonso Vasquez V., same period as above

Field Identification
Mr. Eiji MATSUFUJI, from July 13 to October 28, 1976
Mr. Daikichi NAKAJIMA, July 20 to October 21, 1976

(Bolivian) : Mr. Salvador Aliaga A., from July 25 to October 10, 1976
Mr. Juan Cossio Perez, same period as above
Mr. Eduardo Torrejon G., same period as above
Mr. Prudencia Chuquimia, same period as above
Mr. Ruben Gomez S., same period as above
Mr. Roberto Ramos F., same period as above

5) Content of the Works

Lvelling	: Total length of 610 kilometers
Satellite Observation	: Total 24 points
Field Identification	: Total area of 21,640 sq.km

6) Equipment Used

TOYOTA Land Cruiser (hard-top)	3

TOYOTA Land Cruiser (station-wagon)	5
Doppler Satellite Observation Instrument JMR-1	3
CR Casette Reader of JMR-1	1
SS Signal Simulator of JMR-1	1
2105A Micro Programmable Processor	1
Memory Module (8kw, #008)	1
1/2 Memory System (2102A)	1
BCS/2000 Software (20855A)	1
Teleprinter (2752A)	1
Tape-Reader (12925A)	1
Tellurometer CA-1000	1
Theodolite WILD T-2	2
NIKON Auto Level AE	12
ANRITSU Wireless Apparatus	4
STONAR Wireless Apparatus	7
YAMAHA Boat	6

7) Weather Condition During the Operation

	Jul.	Aug.	Sept.	Oct.	Total	Percentage
Fair	19	18	21	27	85	78.7%
Cloudy	0	11	6	1	18	16.7%
Rain	0	2	3	0	5	4.6%
Total	19	31	30	28	108	100.0%

8) Planning and Achievement

	Planned	Achieved	Reason for Change
Levelling			Because of the difficulty of tree-cutting in the jungle, a part of the levelling in the jungle was substituted and added to the levelling along the river.
Jungle	50 km	20 km	
Mountains	100 km	130 km	
River	200 km	460 km	
Satellite Observation			Because of trouble with one JMR-1 for one month, three points were observed 4 days instead of 10 days
10 days observation	8 points	5 points	
4 days observation	16 points	19 points	
Field Identification	- As scheduled -		

9) Working Situation

With full support of the inhabitants who recognized our works because of the work of the 1st and 2nd Stages of the previous year, the work in the 3rd Stage proceeded smoothly. However, a part of the levelling and a point of satellite observation were forced to be stopped in consideration of the safety of the personnel in the eastern part of the project area (right bank side of the Rio-Ichiro) when we were informed that there were aborigines with poisoned arrows in the area.

In the 3rd stage, the helicopter was fully used mainly for the satellite observation and for mobilization in the project area. The river had to be used since crossing of the jungle was too difficult.

10) Trouble with the JMR-1

One of the JMR-1 (SR. No. 75-195) which was to be used for satellite observation from August 8, 1976 did not work on the site.

The measures taken because of the failure of the JMR-1 were as follows:

July 26 : Tested by signal simulator ... normal
Made satellite observation (test) ... normal

August 7 : Connected inner and outer electrical source

August 8 : Carried from Cochabambe to observation point, Curuzani, in the morning and encountered trouble with the instrument in the afternoon.

August 9 : Checked connections ... normal

August 10 : Despatched a man in charge to the site and rechecked by exchanging the battery, but it did not operate.

August 11 : Brought back to Cochabambe.

August 12 : Checked interior connections, etc. ... Did not operate.

August 13 : Asked an airline company (LAB) to check the instrument. Found that the instrument worked normally, provided electricity of 5 MHZ was supplied from the outside. Then, it was suspected that the trouble was due to either the electric source or the crystal oscillator.
Determined impossible to repair in Bolivia and reported to JICA and the JMR Instrument Inc.

August 16 : Told by JMR to take the instrument to their factory in Los Angeles.

August 23 : Told by JICA to send Mr. Koseki to the JMR factory with the instrument.

August 24 : Mr. Koseki departed for Los Angeles.

After inspection at the JMR factory in Los Angeles, it was found that the crystal oscillator was defective. Mr. Koseki returned to Cochabamba on August 31, 1976 with the repaired instrument after exchanging the crystal oscillator.

The JMR-1 could be used from September 1, 1976.

11) Supervisors of the Works

In order to supervise and teach the methods of satellite observation, Mr. Yamato Miyazaki of Geodetic Division of GSI visited the site from July to August, and Mr. Norio Dobi, Planning Office of GSI visited the site in August, 1976 to arrange for the work of Field Identification.

To make arrangements for the work of the 4th stage, Mr. Naomi Fujita, Geodetic Division of GSI visited on September, 1976 and Mr. Hiroshi Kimura, Social Development Cooperation Dept. of JICA visited on October for receipt and maintenance of the equipment and materials.

B. WORK PREPARATION

1) Main Office

The main office in Cochabamba which was established in the 1st and 2nd stages of the previous year was successively used, in which communication with La Paz and the base camp, analysis of JMR data and accounting were made.

2) Base Camp

A base camp was established at Villa Tunari, the center of the project area. At the base camp, periodic communication with the survey parties, guidance to the helicopter crew and data compilation of the field work were carried out.

And, near the base camp, a heliport for landing take-off of the helicopter was specially set up and also used as a waiting place.

3) Helicopter

The helicopter was chartered from the Airlogistic Company, U.S.A., who has an office in Cochabamba. The chartered helicopter was the Bell-206B type with a five passenger-capacity including the pilot. Two helicopters were chartered from August 5 to October 5, 1976.

4) Employment

An interpreter from the Japanese immigration district of Santa Cruz was recommended by the Japan Embassy in Bolivia and hired, and the laborers were employed through the cooperation of IGM and CORDECO both in La Paz and Cochabamba.

5) Vehicles

The vehicles and boats were rented under contract through the cooperation of CORDECO.

6) Survey Party

The levelling was conducted by 4 parties headed by Mr. Wada, Mr. Mizoguchi, Mr. Sato and Mr. Hayashi, and for the satellite observation, 3 parties headed by Mr. Osakabe, Mr. Nishimura and Mr. Yokota. The work of field identification was executed by Bolivian parties.

C. LEVELLING

1) Method

The same method as adopted in the 2nd stage was taken; both Japanese and Bolivian surveyors observed the same staff simultaneously using respective autoleves and proceeded after checking during a certain interval.

The pin-pricking of the vertical point on the aerial photograph was made by the Japanese surveyor.

2) Accuracy

The closed levelling route was only between PC-J18 and PC-B41. The error was 56 cm in 146 kilometers whose accuracy was satisfactory for the stipulated accuracy of 10 cm $\sqrt{S}$. (S : Km)

The route was mostly along the river, and, similar to the route taken in the 1st and 2nd stages of the previous year, observation was made by setting a staff and level along the bank of the river. Following the river, cross-river levelling was carried out and sometimes 300 meters crossing were made.

For the correction of the atmospheric refraction and carvature of the earth, the following formula was adopted;

$$\triangle H \text{ (mm)} = 0.0000686 \times D^2 \quad (D : \text{meter})$$

3) Others

The levelling along the river in the mountains where the river flows rapidly with a high water level between the steep rock walls was hard work. However, in this year, the helicopter was very advantageous for mobilization in such areas.

The indirect levelling observations using a Tellurometer and T2 were sometimes carried out for such areas since direct levelling could not made due to a big difference in heights.

D. SATELLITE OBSERVATION

1) Method

In order to observe the points which were mostly in the jungle, the helicopter was fully used for mobilization to the point and selection of the point. At the point to be newly established, a concrete pole 10cm x 10cm x 50cm was set as soon as the observation was finished.

5 points were observed precisely for 10 day-and-nights continuous and 19 points were observed for 4 day-and-nights.

The meteorological data was obtained by using an automatic thermometer, automatic psychrometer and automatic barometer.

2) Accuracy

The observed data were recorded on cassette tape of JMR-1 and was processed thru the SP-3 program of JMR.

By the observation of 4 day-and-nights using six satellites, data from 45 passes were obtained and by the observation of 10 day-and-nights using two satellites, data from about 50 passes were obtained.

Such data were processed through the JMR SP-3 program and geographic coordinates and heights were calculated.

The probable error of the computed point averaged 3 meters for φ and λ, and 50 cm in height. The calculated geographic coordinate was transformed in Japan to the coordinate system adopted in Bolivia. The error after such transformation was about 4 meters for X and Y, and about 2 meters for elevation.

The computation using a precise ephemeris are now being processed by DMA in Washington D.C.

3) Others

Part of the observation points in the jungle was made by connecting the pre-amplifier to the bottom of antenna and lifting the antenna for about 4 meters since the cutting down of trees in the jungle was very difficult. In comparison with Japan, good clear data was obtained in Bolivia without any electric wave interference from the 400 MHZ and 150 MHZ frequency.

E. FIELD IDENTIFICATION

1) Method

All items investigated were shown on the contact print. The annotation was prepared from the notes which contained the data together with the name of the investigator, names and address of those who cooperated and date of investigation.

The field identification were mostly carried out on the part of Bolivia.

2) Accuracy

The field identification conducted by the Bolivian side was so detailed that the collected data could be used not only for the 1/50,000 map but also for the 1/10,000 or 1/5,000 map and, further, detailed items for military use were also investigated.

For the Japan side, therefore, the necessary items required for the 1/50,000 map were only extracted and compiled on the contact print with a marking pencil with approval of the Bolivian side.

3) Others

The reasons why the field identification was conducted by the Bolivian side are as follows;

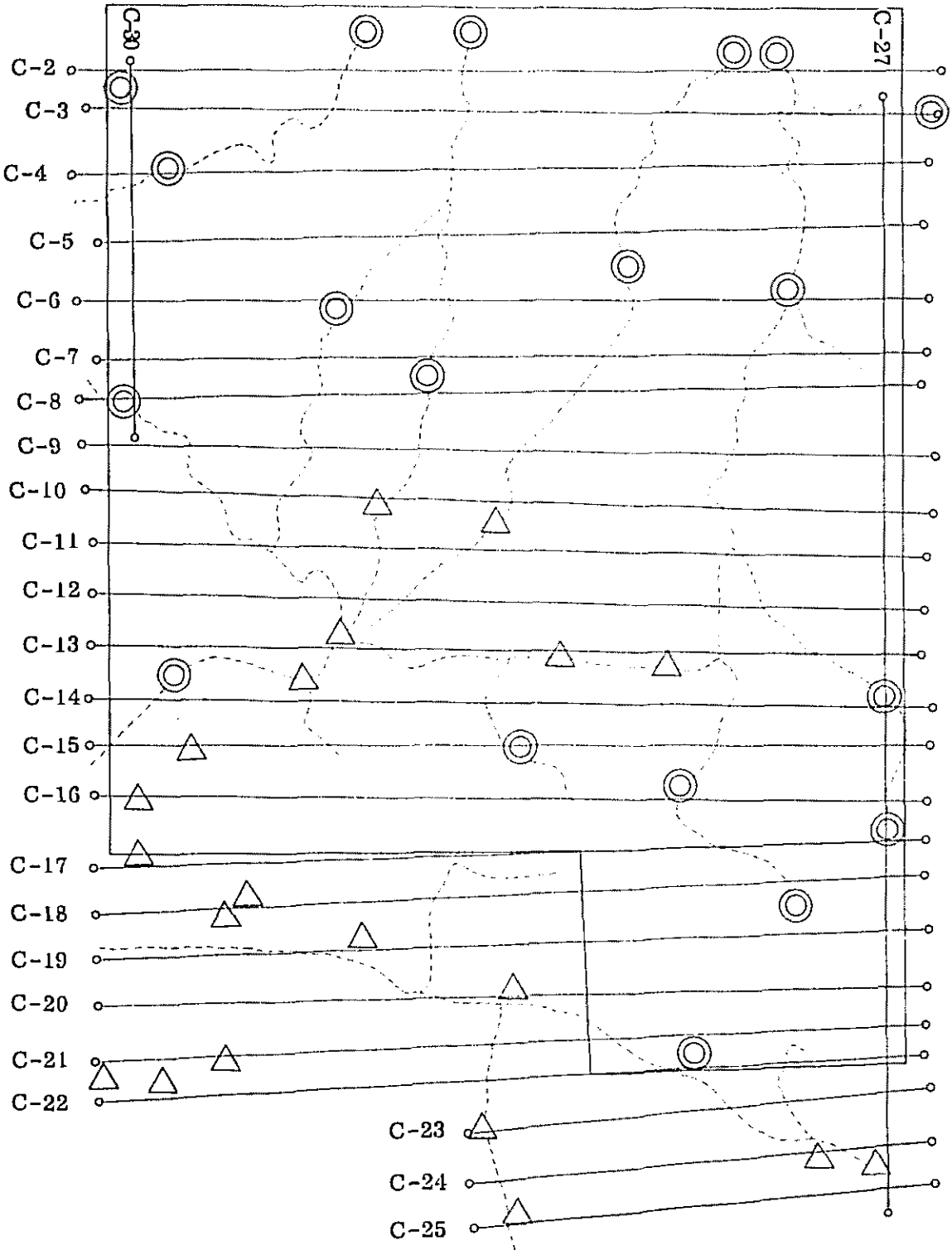
a. It would be better for the Bolivian side to confirm the boundary, topographic names and so on.

b. It was determined that the Bolivian side has the technical skill to execute the field identification and in view of the technical cooperation.

c. The Bolivian side can avoid any mistakes in language and can easily contact the inhabitant for information.

PART II. AERIAL TRIANGULATION

Aerial Triangulation



△ Triangulation Points C2-C13 1 block

◎ Sattelite Observation Points C14-C25 1 block

---- Levelling Route

A. OUTLINE OF THE WORK

1) Purpose

For the photogrammetric mapping at a scale of 1/50,000 for the Chapare Area, Bolivia (approx. 21,640 sq.km), the aerial triangulation was conducted by the analytical method.

2) Working Period

From November 1, 1976 to March 10, 1977.

3) Work Volume

642 models

B. WORKS OF AERIAL TRIANGULATION

1) Work Preparation

In consideration of the location of the ground control points, the project area was divided into 2 blocks, and adjustment computation were made for each block, adopting the analytical method called "Semi-Independent Models Block Adjustment"

In the program for the analytical aerial triangulation, the adjustment of earth curvature and atmospheric refraction was adjusted.

2) Selection of Point

The pass-point and tie-point were pricked on both contact print and dia-positive film correctly so as not to disturb the successive processes. Such points were inked in red circle on the photograph and circled in red "Delmatograph" on the diapositive centering the procked point.

As a general rule, a tie point was selected on one side of each model.

3) Point Transfer

The point were transferred to the surface of the positive film with about a 60 μ hole in diameter, using a WILD PUG-II type of Point Transfer Device.

4) Observation

Fiducial mark and the pricked point, i.e. control (including level) point, pass-point, tie-point and the point specially indicated in the respective model were observes by stereocomparator.

5) Computation

The electric computer, FACOM 230-45S (192K bites) was used for computation of the interior orientation, relative orientation, successive relative orientation and transformation to the Geodetic Coordinate System. So-called "Semi-Independent Models Block Adjustment" was carried out by dividing inot sub-blocks of each 3 models in which error of interior orientation (maximum 30μ), residual parallx in the relative orientation (maximum 30μ) and successive relative orientation (maximum 0.5 0/00 of altitude) were all satisfied.

A block consisted of about 100 sub-blocks or 300 models. The transformation to the Geodetic Coordinate System was based on the formula; The Three Dimensional Orthogonal Transformation.

6) Others

The residual mean error of the aerial triangulation was approximately 3 meters in horizonotal position and about 1 meter in elevation and error of the check line was approximately 2 meters.

The error of the existing aerial triangulation was about 15 meters in length and 5 meters in elevation, and the error of the existing topographic map was 20 meters in horizontal position and 5 meters in height.

Levelling

Satellite Observation

Field Identification